**Is it worth investing in infrastructure to simplify and commercialise space travel?**

**Introduction**

Since the beginning of the space age with the launch of Sputnik 1 in 1957, the task of escaping the Earth’s gravity has presented innumerable problems for scientists and engineers. Over the years, innovative and extraordinary people have come up with an immense variety of unbelievably creative solutions. Despite years of progress and improvement, one key obstacle remains. Cost.

**The Problem**

The cost of launching a rocket into space has always exceeded hundreds of millions. The components of this cost come from varying sources such as the main orbiter, the main fuel tank, the solid rocket boosters, and many others. For this article, I will be focusing on the cost of the fuel required. When prices are adjusted for 2020 inflation, the cost of the single-use fuel tank on the original space shuttle (now retired) amounts to $2.8 billion. This fuel tank was the only component of the space shuttle that could not be recovered and re-used. This meant that for every launch, a new fuel tank would have to be built and fuelled, making launches after the initial research and development far more costly than they needed to be.

Why is so much fuel needed? When escaping earth’s gravity, an object must be accelerated to a certain velocity. This is known as escape velocity. The escape velocity of an object on earth is always the same, regardless of whether it is something as small as a pebble or as large as the space shuttle. 11.2 km/s. In accordance with Newton’s second law, the force required to accelerate an object is directly proportional to the mass of the object. In the case of a rocket, this force is generated by burning fuel to provide thrust. This fuel must also be carried on the rocket, therefore increasing its mass further, resulting in more fuel needed. Due to this, the fuel requirement of a rocket is increased by a much larger factor than it initially appears.

Because of this relationship, the payload carried by rockets into space is very often not as high as it could be. The heaviest payload ever carried to low earth orbit was 141,136kg. When put into perspective with the overall mass of the rocket, 2.9 million kg, this number is extremely inefficient. Even with more modern rockets with more advanced technology to try to even out the numbers the rocket-payload ratio is still approximately 20:1. This is little to no improvement which means a new approach must be considered if space travel is to become sustainable and commercial in the near future.

**What can be done?**

The next logical step would be to look for ways to make reaching low earth orbit much less fuel heavy and to also find a way to make repetitive and consistent travel a reality. The most obvious solution to this would be to consider more permanent infrastructure to be built on earth. This would work similarly to a road. Faster and more advanced cars can always be produced; however, a road would increase the overall productivity and efficiency of all vehicles that use it.

Many ideas have been put forward to be a potential solution to this problem and a few of these ideas have been listed below.

**The Space Elevator**

The first idea is a space elevator, first suggested in 1895 by Russian Scientist- Konstantin Tsiolkovsky. The core concept of this suggestion is quite simple. Essentially having an artificial satellite at geostationary orbit (this is the altitude at which orbital speed matches the rotation speed of the Earth). This would extend a cable down to ground level, allowing an attached chamber to travel up and down freely, using the cable as support. Throughout the years this idea has been re-imagined in many different ways with many different improvements. The most recent version as of today consists of a counterweight on the other end of the cable situated so that the centre of mass is at geocentric altitude. This means that the centrifugal force generated by the rotation of the earth is enough to pull the cable taut on its own.

This idea has been an extremely popular concept for a long time however it has never been realised. The main reason for this is simple. We do not have the technology to make it work reliably. In order for this method to work, the initial issue is manufacturing a cable strong enough to withstand extending all the way to low earth orbit and be held up by only the centrifugal force of the counterweight. The second difficulty is being able to establish the counterweight in the correct place and keep it there for a long period of time. Perhaps with continued research, development, and a large investment, this idea could be made into a reality, however, for now it remains science fiction.

**The Moon Base**

Another interesting concept worth mentioning is that of a moon base. The idea of a moon base is a very attractive option for further solar system exploration. There are many key reasons behind this. All missions launched from the moon would have to reach a much lower escape velocity, due to the lower gravity. Compared to 11.2 km/s on Earth, a rocket escaping the moon’s gravity would only have to be accelerated to 2.38 km/s. This is close to 1/5 of the escape velocity on earth. As stated previously, the overall fuel required would also be much lower, due to the mass calculation. On top of this, there is next to no air resistance on the moon, therefore a streamlined design is much less important, and the design of the rocket can instead focus on accommodating wider payloads.

While the moon base does seem like an excellent future potential project to be undertaken by humanity, there are some major flaws with it. The first issue is that in order to construct the moon base with current technology, rockets would still have to make several hundred return trips to the moon in order to deliver materials and supplies for the workers. Even worse, is that once the base is established, missions must still be originally launched from earth. This means that this solution is impractical to consider before we are able to find a solution to make escaping earth easier.

**Momentum Exchange Tether**

The final idea discussed here is that of the Momentum Exchange Tether, informally known as the tether slingshot method. This involves making use of the earth’s gravitational field to help escape the earth’s gravitational field. As can be seen from this summary, if executed properly, this method can be highly efficient in launching ships into orbit and deeper space.

This method works by establishing a satellite in orbit and extending a cable from it. Unlike the space elevator, however, this cable does not extend to the surface of earth. Rather, it would be approximately 11-12 km above sea level at the cable’s closest approach to earth. This is similar altitude to most commercial planes, therefore much easier to reach. The satellite rotates about a fixed point which is the centre of its orbit over the planet. On one side, from a short distance from the centre, is a large counterweight. On the other side, a long cable is extended, it is this cable that will reach down to earth for spacecraft to latch on to. Due to force multiplication laws, the centre of mass is the fixed point that orbits the earth. The gravitational force exerted by the earth pulls on the centre of mass, causing it to fall forwards. This is how orbit works. The orbit of the cable will allow it to rotate indefinitely, with very little need for adjustments. As it is a mass in motion, it has momentum. When a spacecraft latches on to the cable at its lower end on earth, it will be carried up far beyond the bulk of the atmosphere. Upon reaching the furthest point from the surface, the spacecraft will detach from the cable, and some momentum will be transferred to it, propelling it into deeper space, using no more fuel than a commercial aircraft.

As for the cable, due to conservation of momentum, due to the leaving spacecraft, it will inevitably lose some of its momentum. This will cause it to decelerate slightly and drop slightly lower in its orbit. This will become very problematic after many repeated launches, as this may cause the central satellite to crash into earth. A simple solution to this issue would be to attach small correction thrusters to the central satellite. This can ensure that any lost momentum can be added back on and keep the tether in optimal position. As well as this, once space travel becomes more frequent, the tether could also be used to ‘catch’ spacecraft arriving back to earth. When it is used this way, the momentum exchange will be in the opposite direction, with the tether decelerating the spacecraft, and the momentum being transferred to the tether, increasing its velocity. In this way, the tether can remain somewhat stable in its orbit with lots of ships both launching and arriving, keeping the overall momentum balanced, with very little need for small adjustments by the thrusters. This form of infrastructure will allow payloads to be launched into space much cheaper and much more efficiently. The main advantage of this system is that it is entirely possible to achieve with current technology. With the use of this technology, even better technology, such as the moon base mentioned above, becomes accessible.

**Why should we do it?**

Now that a suitable solution has been identified, the question arises: Why should we do it? Why should we focus on going to space?

There are numerous advantages that come with colonising space. By far the most notable are accessing more resources to meet the demands of an ever-increasing population, and providing living space for more people, reducing the strain on our home planet.

It is no secret that earth is being exhausted at a constantly increasing rate. The exponential growth of the population means that, in coming years, the threat of overpopulation will seem more immediate and threatening than ever before. Rather than start controlling key aspects of life; rationing land, resources, and even children, extending humanity beyond our single planet can help us keep life enjoyable, and ensure there are enough resources for all.

Some may argue that there are enough issues on our world as there is, expanding to space is unnecessary for the time being and should not direct the attention of major governments. My response to this argument would be, while it does seem unnecessary for the time being, the point at which it will become necessary is rapidly approaching, it would be much more beneficial to plan and prepare long in advance rather than rush and make costly mistakes when the time comes.

My final point is that space tourism and colonisation will open many more jobs, thus, solving some of our current world affairs. If we are to set up colonies on other planets, people will be needed to carry out the tasks that come as a result. This would create more jobs for people who are able to live in harsh conditions, such as those living in poverty in third world countries. As well as this, the experience of being in space is one described as many that have been to space as ‘unforgettable’. To help more people than ever before experience the wonders of zero gravity is a goal we should all work towards.